An Internationalized Cultivation Mode of Practical Ability of Industrial Engineering under the Emerging Engineering Education

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***Abstract*—While the Emerging Engineering Education is the new trend of education in China, the curriculum system of Industrial Engineering is not timely and comprehensive enough. Thus, it is necessary and urgent to attach more attention to the practical cultivation of engineering students. To address these problems better, the Industrial Engineering discipline in Huazhong University of Science and Technology proposes an internationalized educational idea based on the practice-driven innovation that an open and collaborative cultivation system throughout the overall undergraduate course should be constructed. More specifically, engineering practice and innovation education are required to be more multi-disciplinary, multi-party collaborative and student-centered to solidify the innovative talents and broaden the international vision of Industrial Engineering students. Though this exploration of talent cultivation mode of Industrial Engineering discipline in Huazhong University of Science and Technology, it is also expected to contribute to the general development and innovation of Emerging Engineering Education in China.**

***Keywords*—emerging engineering education, internationalized, industrial engineering, cultivation mode**

I. Introduction

China became the 18th full member of the Washington Accord in 2016 and after which the Ministry of Education in China launched the research of the Emerging Engineering Education. Fudan Consensus, Tianda Action and Beijing Guide are three programmatic documents indicating the direction of higher engineering education improvement in China [1]. The Emerging Engineering Education (3E) is a new direction of engineering education reform in China based on the new demands of national strategic development, new situation of international competition, and new requirements of moral education [2]. The latest development direction should be innovative, environmental-friendly, people-oriented and human-oriented. The word 'emerging' not only indicates new development of technology, but also higher requirements of talents cultivation.

As a systematic and comprehensive discipline, Industrial Engineering (IE) promotes interdisciplinary synergy of science, engineering, liberal arts, management and medical science by solving complex engineering problems. The industrial world is currently improving and is also transforming towards a more advanced industry [3]. The State Council of China announced the "Made-in-China 2025" Plan in May 2015, which signals China's intention to launch an industrial transformation from labor intensive production to knowledge intensive manufacturing, and usher in a major breakthrough at a fast speed [4]. At present, manufacturing industry in China is in the stage of transformation and upgrading. Without doubt, there will be newer and greater development of Chinese industry in the future. Accordingly, IE will gain wider application and development potential, as a powerful tool of optimizing industrial production. The rational use of IE technologies and methods will significantly promote faster and better development of Chinese enterprises, which requires the discipline construction of IE in China to keep up with the development of science, technology, and economy. From the perspective of interdisciplinary intersection as well as talent cultivation mode, IE has the same goals as the Emerging Engineering Education. By analyzing the current problems of IE education in China, this paper proposes an internationalized mode of cultivating practical ability of IE students, which will contribute to the exploration of talent cultivation mode of the Emerging Engineering Education in China.

II. Challenges of the Construction of Industrial Engineering Discipline

Professional Industrial Engineers are currently in high demand across the world [5]. In the United States, Industrial Engineering, as one of the seven independent engineering disciplines, has led the technological innovation and development under multidisciplinary

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integration. IE has also been fully developed and applied in Japan. However, it started late in China, and there are still many deficiencies in specialty construction.

A. Timeliness of the Course

As the development of global new economy and new industries is rapid, the training goals of the Emerging Engineering Education are constantly changing accordingly. At present, the curriculum system of IE cannot meet the needs of the new economy in terms of knowledge and innovation ability. In the meanwhile, the existing cultivation mode of IE separates theory and practice, and students lack the industrial background to deeply understand theoretical knowledge. Moreover, many theoretical knowledge imparted in class lack pertinence and cutting-edge. As a result, the knowledge is difficult to be applied in practical operation, but it is easy to be forgotten. At last, it cannot achieve the transformation from knowledge to skills.

B. Comprehensiveness of the Curriculum System

In China, colleges and universities with IE majors often attach it as a secondary discipline to the College of Machinery or the School of Management. For example, in Huazhong University of Science and Technology (HUST), IE is a secondary discipline of the mechanical science and engineering, without obvious discipline characteristics of its own. Moreover, there is a lack of interaction and relevance between the relevant courses, and the discipline is not systematic enough, which will inevitably affect the cultivation of comprehensive application ability.

C. Simplicity of the Practical Training

Taking HUST as an example, practice training is mostly arranged in senior grades, with limited time and basic goals. The general link of 'production practice – curriculum design – graduation design' is basically completed in the campus, and the practical links related to the industry are mainly visiting and looking around factories and companies. Teachers and students rarely have the opportunity to deeply understand the actual industrial needs.

D. Fragmentation of the Educational Resource Ecosystem

The foresightedness, depth, and difficulty of scientific research in the internal ecosystem of talent training composed of schools and teachers make it difficult for undergraduates to deeply and systematically intervene, and its coverage is also limited. On the other hand, the international advantageous resources aimed at promoting students' international vision are all based on intercollegiate exchanges and visits, as well as short-term lectures by professors. Thus, the audience groups of undergraduates are small, and they cannot make an obvious influence in a short time.

In response to the above problems, HUST, while taking root in the development of specialty characteristics, has explored the cultivation mode of promoting IE talents' practical ability from the perspective of the national strategy, the need of industrial multidisciplinary talent training, and global visions. It has carried out reform and innovation in terms of cultivation concepts, training systems, practical teaching content and methods, and pilot projects have been carried out on three sessions of students.

III. Internationalized Talent Cultivation Concepts Based on Practice-Driven Innovation

A. Practice Education is the Fundamental Method to Cultivate Outstanding Engineering Professionals

In recent decades, China's engineering practice education has been developing steadily. Experts and scholars in this field have gradually realized the importance of engineering education for social and economic development and the importance of engineering practice education. For IE, such a specialty with strong practicality, practice training is the key link.

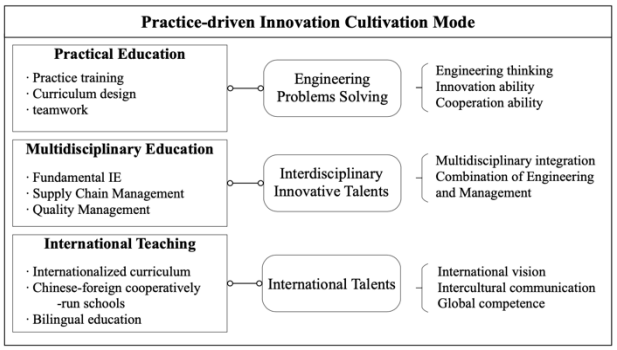

Fig. 1. Talent cultivation mode based on practice-driven innovation.

Practice is the essence of engineering and the basis of innovation. Engineering practical education aims to improve students' engineering practice ability and professional engineering knowledge, especially for science and engineering students, so that students can meet the society's demand for engineering technology or management talents. In the engineering field, students can acquire and practice different technical skills under supervision [6]. As the era of knowledge economy comes, knowledge is divided into explicit knowledge and tacit knowledge. The latter is highly personalized knowledge obtained from practical experience and difficult to code or share with others, which is also the basis of individual competitiveness. Tacit knowledge is not easy to be imitated and copied, but it is essential in engineering activities. The understanding of practice that emerges from contemporary research could help educators to shape a new generation of engineers with skills that are better suited to restoring global productivity growth and transforming economies [7]. Therefore, in order to cultivate top-notch innovative talents and outstanding engineers who can meet the needs of the industry and adapt to the future development, HUST has adopted the internationalized talent training mode of practice-driven innovation (see Fig. 1). With practical education as the core, let students improve engineering thinking in multi-level and multi-mode practical education, and improve

their innovation ability and teamwork ability. In terms of curriculum system, HUST focuses on interdisciplinary, integrating engineering technology and management science. In addition, international teaching methods such as the internationalized curriculum system and the concept of Chinese-Foreign cooperatively-run schools are used to broaden students' international vision and improve the intercultural communication ability and global competitiveness.

B. Integrating Practice and Innovation to Solve Complex Engineering Problems

The Washington Accord specifies that undergraduate education aimed at training engineers must have the ability to solve complex engineering problems in the first place. Complex engineering problems are comprehensive problems with a certain scale, complexity, and can be affected by non-technical factors, which will occur in actual engineering activities. Complex engineering problems are not simply traditional technical problems, but closely related to human society, economy and environment. With the only help of professional knowledge and technical ability, the problems can hardly be solved (see Fig. 2).

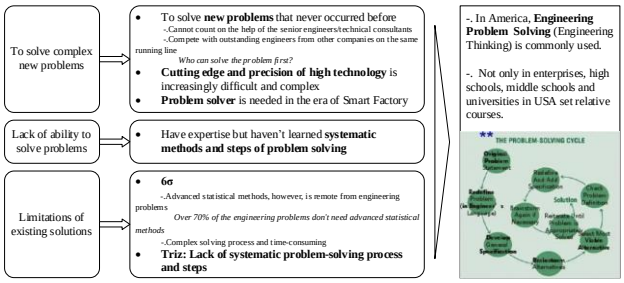

Fig. 2. To solve complex engineering problems.

To solve such problems, innovation on the basis of existing technologies and methods is the key. And adaptability analysis and transformation must be carried out in combination with engineering practice. Only through personal practice and full thinking in the process can students accumulate experience, optimize and innovate, and then solve practical engineering problems. Thus, the practice platform of complex engineering problems is the basis of engineering practice education and innovative thinking training.

C. Interdisciplinary Practice is a Critical Link of Innovative IE Talents Cultivation

The feature of modern scientific and technological innovation and development is that it is highly differentiated and highly integrated. The increasing breadth and depth of discipline intersection has become an influential factor of innovation. The intersection and integration of multiple disciplines are the foundation of modern scientific and technological innovation.

Industrial engineering, as one of the seven engineering disciplines, has been a multi-disciplinary composite specialty since its appearance, with strong characteristics of engineering practice. In terms of IE cultivation in China, the Guidebook of Industrial Engineering Term Project (see Fig. 3), published by the Ministry of Education, includes experiments of fundamental IE, human factor, manufacturing planning and control, quality management, construction planning and logistics analysis, as well as basic information technology. Through the organic combination of different professional directions and multiple disciplines, to build a completed practical training system, guide students to learn independently, practice and innovate actively, which is the key to cultivating comprehensive talents with a variety of knowledge backgrounds, reasonable knowledge and ability structures, solid foundation, comprehensive quality and strong adaptability.

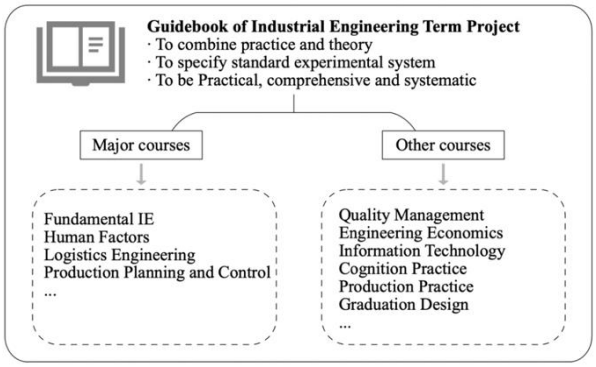

Fig. 3. Guidebook of industrial engineering term project.

D. International Vision and Intercultural Communication Ability

Economic globalization has promoted the internationalization of China's industry. Chinese society is also in urgent need of high-level talents who master both professional technology and international practices of project management and relevant laws. Research shows that IE talent cultivation needs to carry out reform of international integration, so as to train high-level IE talents with innovative ability, international vision and, meanwhile, adapt to China's economic and social development. An individual who does not have international vision or affinity cannot become a leader and a pillar. On the contrary, talents with cross-cultural experience are most popular with society and enterprises. Therefore, industrial engineering needs international education reform to cultivate innovative talents with international vision, and to greatly improve their knowledge, ethical quality, communication and cooperation ability.

To achieve this goal, the reform of IE education should focus on establishing international talent training ideas, building an international curriculum system, carrying out international cooperation in running schools, and cultivating international teachers.

IV. The Internationalized Curriculum System of IE Specialty in HUST

Huazhong University of Science and Technology, as a globally-influential university, attaches great importance to the cultivation of innovative engineers. The training

objective of the industrial engineering in HUST is to cultivate students with scientific, engineering and humanistic qualities, basic knowledge and application ability of enterprise management, computer technology and mechanical engineering. Moreover, with higher English level, computer application ability, management knowledge and technology, and ability to work in production enterprises, including machinery, electronics, computer application, finance and services, the compound talents are able to engage in the analysis, planning, design and management of various complex management and production systems and master both technology and management.

A. *The Internationalized Curriculum System of IE Specialty in HUST*

Based on the advanced experience of IE major in American universities, the IE curriculum system in HUST focuses on basic disciplines and interdisciplinary integration. The general courses of quality education accounted for 27.1% in total. The basic courses and professional courses take up 30.3% and 34.1% respectively, and the collective practical training accounted for 8.5% (see Fig. 4). Extracurricular credits attach more importance to social practice, English application, computer ability, science and technology competitions, patent and practical innovation. The new curriculum system requires students to be able to use mathematics, natural science, and professional knowledge to solve complex engineering problems; to systematically master the technical theory and basic IE knowledge; to have the ability to analyze and solve the production organization and management problems of the enterprise; to have strong self-learning ability and innovation consciousness, and to understand the discipline frontier and development trend; to have an international perspective and cross-cultural communication ability.

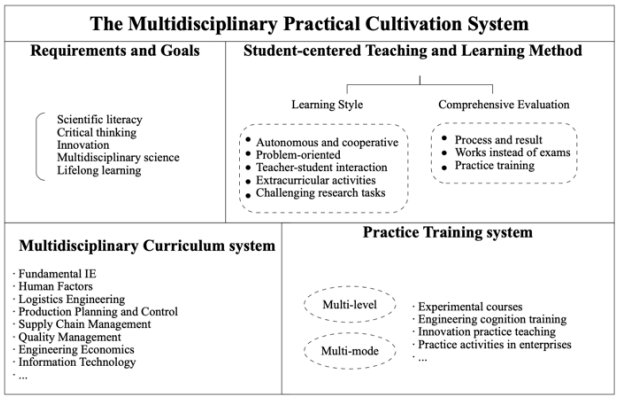

Fig. 4. The multidisciplinary practical cultivation system.

B. *The Internationalized Training Methods of Innovation Practice of IE specialty in HUST*

On the basis of the curriculum system, the IE specialty of HUST attaches importance to the practical innovation links, and has built a student-centered practice platform providing multi-level and multi-mode practical training. With the Industry-university Research and international cooperation as its core, the practical training system integrates multi-channel and high-quality resources such as foreign universities, international academic institutes, industrial cooperation and international innovation projects (see Fig. 5). The recourses are effectively integrated into the all-round talent training link.

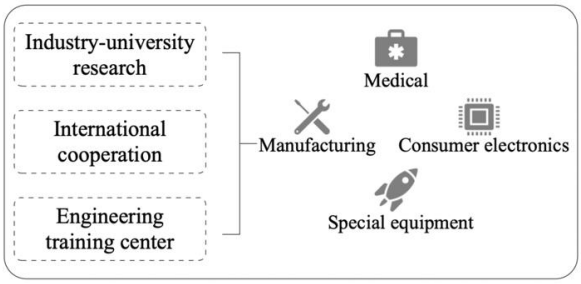

Fig. 5. Practice platform.

1) *Cultivation system*

Generally, the cultivation system includes curriculum knowledge and practical training. The curriculum system is a combination of professional major courses and multidisciplinary courses to meet the requirements of comprehensive knowledge background and personalization of IE education. In terms of practical teaching approaches, it builds a collaborative education mode that integrates production and learning between schools and enterprises. A standardized science-education coordination mechanism based on practical courses is established to promote students' scientific research skills and confidence, professional interest, critical thinking, and ethical awareness. The practical courses cover a wide range of fields including medical, manufacturing, consumer electronics, and special equipment. To launch international reform, HUST actively cooperates with internationally renowned universities and absorbs international advanced experience in running schools. At the same time, there are various high-level long-term and short-term international exchange projects for students to participant in.

2) *Teaching methods*

When it comes to the teaching methods, HUST has deeply integrated information technology and engineering practice education. Problem-Based Learning (PBL) can function as an effective teaching pedagogy to enhance professional skills for engineering students [8]. On this basis, the IE specialty in HUST has transformed into student-centered, personalized, and hybrid teaching form. It provides a flexible and promotable new practical mode of teaching and learning, which includes: Problem-oriented Learning to enable students to quickly contact and understand practical engineering problems; Autonomous and Personalized Learning to make students personalize learning goals and independently obtain corresponding resources to complete tasks under the guidance of teachers; Challenging and Research-based Learning of teamwork and project practice: students complete projects and scientific and technological innovation activities through teamwork, and solve complex engineering problems through interdisciplinary collaboration. In addition, HUST makes full use of its extensive international exchange and cooperation

resources to carry out internationalization of teachers. On the one hand, teachers are sent to exchange and study abroad, and on the other hand, famous professors are invited to guide the teaching methods of relevant courses. And then, a series of professional courses adopt bilingual teaching, such as Human Factors Engineering, Management, Logistics System Management, etc. It explores the international teaching mode of English teaching in terms of language communication skills, knowledge acquisition, teaching materials, and assessment.

3) Practice resources

HUST makes use of the advanced scientific research platform, infrastructure, technology transformation platform and other resources to jointly build an engineering practice innovation platform open to all students. Based on the interdisciplinary research projects and achievements, it carries out student-centered teaching reform to cultivate students' practical innovation awareness, innovative thinking, and innovative ability by stages, levels, and classifications. Combining industrial scenarios, engineering problems, cutting-edge technology, and advanced equipment, a production-teaching environment and a cognition-practice-innovation practice system are created for students.

4) Evaluation system

HUST has established a comprehensive academic evaluation system. In order to ensure the teaching quality, strict evaluation and supervision standards are adopted. The evaluation mode gradually shifts from the result evaluation to the process-result evaluation, to promote the diversification of assessment methods. Besides, the assessment methods attach more importance to ability, process, and practice, such as taking works or reports instead of examinations. In addition, students' opinions and suggestions on the courses are collected to timely modify the course content in line with the cutting-edge trend of the discipline.

C. Practical Case: Interdisciplinary Talent Cultivation Based on the Smart Elderly Care Project

HUST has cooperated with the University of Toronto and established a smart elderly care joint research center. Based on the research center and professional practice platform, and with the industrial application background of intelligent elderly care, the IE specialty puts forward the professional ability training methods including student-led problem analysis, cross-cultural team cooperation, and problem-driven multi-disciplinary knowledge learning.

First of all, the modular design of the project focused on the design of human-computer systems in the field of intelligent health care. According to the training objectives and outline of Human Factors, Fundamental IE and Advanced Human-computer Interaction and Interface Design, problem solving approaches and knowledge trees were established. The development goal, difficulty, time and task quantity of each module of the project were defined according to the teaching time, number of students, and professional foundation of students. Secondly, it adopted the method of cross-cultural collaborative research and practice. Teamwork is considered a key skill in engineering [9]. Based on the joint research center, it focused on the needs of the smart health care industry, a China-Canadian student research team was established to carry out training in cross-cultural communication skills, network working methods, and other aspects, so as to improve the students' ability of international cooperation. What's more, it adopted the project promotion method of strong coupling of multiple training links. Based on the idea of modular design, a complete knowledge and skill decomposition tree was established for the overall implementation goal of the project according to the span of two academic years, which ensured the continuity of knowledge and skill learning planning in the process. And the assessment methods were improved for the practice links of each course to supervise and encourage students to persevere in project implementation, independent system planning, and self-discipline teamwork.

V. Conclusion

Under the guidance of 3E, this paper analyzes the current situation of industrial engineering education in Chinese universities. Among them, the problems of timeliness and comprehensiveness of curriculum system, uniqueness of practical cultivation links and educational resources are the major challenges of the current education reform. In response to these problems, this paper puts forward the international talent cultivation concept of practice-oriented innovation. It points out the importance of engineering practice education, innovation cultivation, multi-disciplinary intersection, and internationalization education for the cultivation of engineering talents. On this basis, this paper also proposes an internationalized system for cultivating innovative talents in industrial engineering, which includes a multi-disciplinary practical cultivation curriculum and internationalized innovative cultivation methods from teaching methods to practice platforms. Future improvements to the course will be directed toward a more formal and practical approach to the methods of systems engineering [10]. Finally, this paper analyzes a specific case of multi-disciplinary talent cultivation based on complex problems in the field of smart aging, based on the joint research center of smart aging established by industrial engineering of Huazhong University of Science and Technology and the University of Toronto. In conclusion, this paper hopes that the proposed model of international cultivation of practical ability of industrial engineering talents can meet the needs of talent cultivation and provide a new perspective of IE education reform.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: Yan Fu; Investigation: Yan Fu and Zhengke Gao; Methodology: Yan Fu and Zhengke Gao;

Supervision: Yan Fu, Zhengke Gao, Hao Li, and Junfeng Wang; Validation: Yan Fu, Zhengke Gao, Hao Li, and Junfeng Wang; Writing: Yan Fu, Zhengke Gao, Hao Li, and Junfeng Wang; all authors had approved the final version.

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